PROFFERED PAPERS: GEC-ESTRO 1: PHYSICS 1

OC-0081

Collapsed cone dose calculation algorithm for HDR brachytherapy: Validation and evaluation using Monte Carlo

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Purpose/Objective: The standard algorithm used for dose calculations of HDR brachytherapy plans conforms to the AAPM-TG43 formalism. Since this formalism is based on dose calculations in infinite water phantoms, its accuracy is limited in conditions such as near the body contours or in presence of inhomogeneities. On the other hand, Monte Carlo (MC) methods are able to calculate dose distributions very accurately. However, due to rather long computation times, MC methods aremainly used as benchmark for other dose calculation algorithms. In this work we present a validation and evaluation of the collapsed cone (CC) algorithm [1] with MC.
Materials and Methods: In a first step, the Nucletron brachytherapy source microSelectron-HDR v2 has been implemented in the MC environment and validated against published AAPM-TG43 data from Taylor & Rogers [2]. For this purpose, the dose in a water sphere has been scored for a single source placed at the center. Furthermore, the CC algorithm has been validated, by comparing CC and MC calculated dose distributions for a single source placed at the center of a water cube. Primary and scatter dose components have been calculated according to the dose separation (PSS) formalism and compared individually. The second part of this work consists of the evaluation of the CC algorithm using 10 clinical treatment plans for breast cancer patients. For these plans, dose distributions have been calculated with CC and MC.
Results: The local difference between the MC calculated dose distributions in the water sphere andthe AAPM TG43 data is less than 1%. The comparison between the CC algorithm and MC in the cubic water phantom shows differences up to 2% of the reference dose (dosein 1 cm from the source on its equatorial plane) for distances > 2 cm from the source. These differences can be assigned to the first and residual scatter dose component, while the primary dose component is accurately modeled. Calculated CC doses on clinical breast cancer cases in general agree well with dose distribution simulated with MC. In the high-dose region (> 100% of the prescribed dose), CC underestimates the MC dose by as much as 2%. It was found that this deviation is correlated with the geometrical size of the CT data set. If the CT data set extends the PTV by an appropriate amount, the underestimation falls below 1%.
Conclusions: The CC algorithm is an accurate dose calculation algorithm and improves the dose calculation accuracy in brachytherapy, particularly for situations where the AAPM-TG43 formalism has some limitations. This work was supported by Nucletron.
References:
[1] Å. K. Carlsson and A. Ahnesjö, The collapsed cone superpositionalgorithm applied to scatter dose calculations in brachytherapy, Med. Phys. **27**,2320–2332, 2000
[2] R.E.P.Taylor, D.W.O. Rogers, EGSnrc Monte Carlo calculated dosimetry parameters for ^{192}Irand ^{169}Yb brachytherapy sources,Med. Phys., **35**, 4933—4944, 2008

OC-0082

Collapsed Cone superposition algorithm for the dose calculation in brachytherapy using optimal kernel sizes

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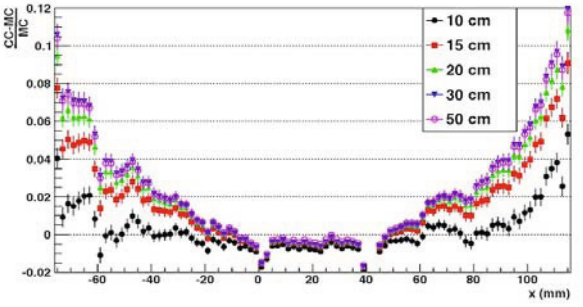
Purpose/Objective: The brachytherapy (BT) version of the collapsed cone (CC) algorithm is under implementation in the Oncentra treatment planning system (Nucletron – an Elekta Company, Veenendal, the Netherlands). CC is a point kernel superposition algorithm that treats the dose from multiply scattered photons with the approximation of the phantom size used to generate the kernel. This study assesses the performance of the CC with various clinical cases with kernel sizes selected to take into account the finite phantom size and the presence of material interfaces.
Materials and Methods: In this work we use the BT CC algorithm version 0.4.0 to calculate the dose in a number of clinical prostate and breast cases. Point kernels for residual scatter were derived in water phantoms of different dimensions with radii ranging from 10 to 50 cm. Results are compared with Geant4 Monte Carlo (MC) simulations using the same geometries and material descriptions based on the complete DICOM-RT data. Criteria based on DVHs and the local dose agreement at interfaces determine the optimal kernel size to use in each case. All calculations were generated using a relatively high number of cones, 720 and 500 for the first and residual scatters respectively.
Results:



Prostate HDR brachytherapy cases were calculated in a voxelized geometry containing 96^3 voxels (each 2x2x2mm^3). A smaller kernel size of 10 cm substantially improves the general agreement with MC over the entire phantom volume in comparison to the default value of 50 cm. As shown in the figure for a typical prostate case, the CC overestimation towards the phantom edges decreases from 12% to less than 4% using a 10 cm kernel in prostate cases. Dose profiles in peripheral organs at risks like the rectum and bladder are accurately described with the latter choice. The measured D90 parameters are all precise at the 1% level irrespective of the kernel size. Slightly better values are obtained close to the source positions with larger kernel sizes, suggesting that a better agreement could be obtained with a choice of kernel sizes dependent on the distance to the closest boundary. A situation with tissue-air interfaces like in a breast case would also benefit from smaller kernels and a treatment with a Mammosite applicator has been studied. A 10 cm kernel gives better dose predictions and improves the skin dose to a precision below 2% relative to MC; this represents a two-fold reduction compared to the larger kernels.
Conclusions: This study suggests that tissue-air interfaces in breast cases as well as limited-size geometry in prostate cases are described accurately using smaller kernel sizes. An adaptive kernel sizes selection would further improve the performance of the algorithm to all regions of interests.

OC-0083

Comparison of TG-43 and TG-186 in breast irradiation using a low energy electronic brachytherapy source

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Purpose/Objective: The TG-186 report has updated guidelines for reporting dose in brachytherapy. The current TG-43 protocol ignores the effects of tissue heterogeneity and patient geometry on dose distributions from low energy sources(<50keV). One alternative dose calculation method is Monte Carlo (MC) dosimetry, which can accurately calculate dose distributions in realistic patient geometries such as those derived from CT imaging. A miniature low energy electronic x-ray source, Xoft Axxent, is currently used for accelerated partial breast irradiation (APBI). Recent literature indicates the importance of properly segmenting adipose and mammary tissue for breast dose calculation with low energy photons. The purpose of this study is to highlight the importance of proper tissue segmentation, applicator modeling and radiation transport in APBI by reporting the dose discrepancies stemming from the usage of TG-43 dosimetry.
Materials and Methods: The GEANT4 Monte Carlo code was used to simulate dose distributions in 8 APBI patient geometry. Patient CT images were voxelized and segmented into various tissues based on a breast modeling scheme. The balloon applicator was modeled using manufacturer's data. The source was a phase space file derived from

the validated source model. The MC simulations were done using the original treatment parameters; source strength, dwell positions and times. The MC dose metrics for PTV and skin D_{90} and $D_{0.1cc}$ were compared to the TG-43 treatment plan.
Results: A validation simulation using a water-based geometry agreed to within 1% of the treatment plan's D_{90}. The patient dose was scored in terms of dose to water in medium ($D_{w,m}$) and compared against the TG-43 plan ($D_{w,w}$) (figure). All dose metrics demonstrate a decrease in $D_{w,m}$ compared to $D_{w,w}$ on the order of 10-30%. The TG-43 D_{90} is reduced by 20% in $D_{w,m}$. The $D_{0.1cc}$ for the skin showed a 30% reduction when recalculated in MC. The reduction is the result of a complex combination of factors such as tissue heterogeneity, loss of backscatter at the skin/lung interface and the applicator design, in particular the wall of the balloon applicator which reduces the dose fluence by approximately 7% due to the presence of barium sulfate (a high-Z compound).

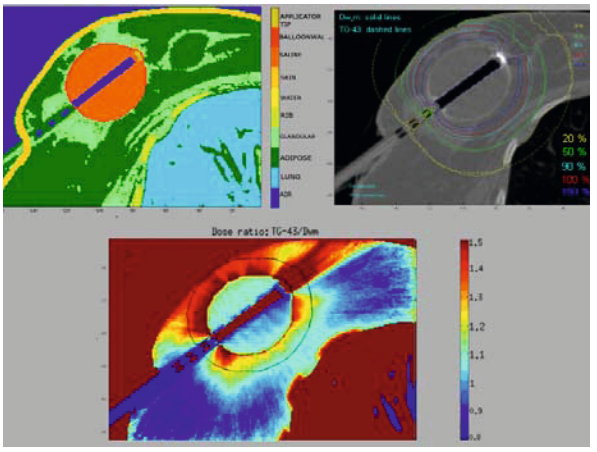

Figure: Top Right: Isodose comparison of MC-based(solid lines) versus TG-43-based dosimetry (dashed lines) Bottom: Ratio of $D_{w,w}$ to $D_{w,m}$. Black lines denotes PTV. $D_{w,m}$ to air/lung is reported as zero. Top left: HU-based tissue segmentation of the breast.

Conclusions: Results indicate that effects of under-dosing on the dose distribution for Dw,m compared to Dw,w. This study demonstrates the need for more comprehensive dosimetry model to the current TG-43 dose formulation.

OC-0084
How to specify dose to water using model based dose calculation in brachytherapy treatment planning?
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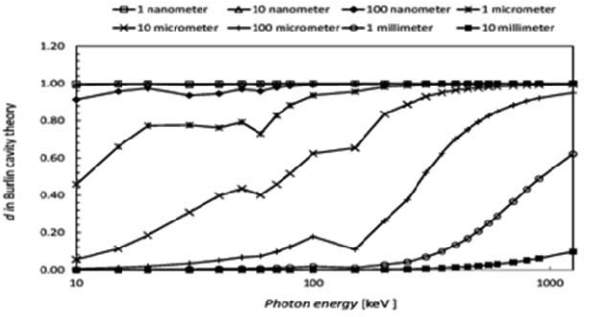
Purpose/Objective: Model based dose calculation algorithms (MBDCAs), recently introduced in treatment planning systems for brachytherapy (BT), calculate absorbed doses to the medium (i.e. to the tissues). The aim of this work was to shed light on the yet unresolved issue of which method for converting absorbed dose to medium $D_{m,m}$ into absorbed dose to water $D_{w,m}$ is most suitable for BT. 'Small cavity theory' implies conversion by stopping power ratios and is applicable when ranges of secondary electrons are long compared to cavity dimensions while 'large cavity theory' implies conversion by ratios of mass energy absorption coefficients and is applicable when ranges are short in relation to cavity dimensions. The relationship between cavity size and applicable cavity theory at the photon energies of interest to BT, i.e., in the energy range 20-1000 keV, was investigated. An argument in favor of reporting $D_{w,m}$ has been that there exists a radiotherapy target being of cellular dimensions that is more water-like in all tissues than the average bulk medium obtained from CT images and used in MBDCA calculations.
Materials and Methods: Burlin cavity theory was applied to estimate photon energies at which cavity sizes in the range 1 nm -10 mm can be considered small or large. Photon- and electron energy spectra were calculated at 1 cm distance from the central axis in phantoms of bone, muscle and adipose tissue for centrally placed 20, 50, 300 keV, ^{125}I, ^{169}Yb and ^{192}Ir photon point sources; ratios of mass collision-stopping powers and mass energy absorption coefficients were calculated as applicable to convert D_{med} into $D_{w,med}$ for small and large cavities.
Results: The figure shows the parameter d in the Burlin theory as function of photon energy and cavity size; a cavity is small when d is close to unity and large when d is close to zero.
1-10 nm sized cavities are small at all investigated photon energies; 100 µm cavities are large only at photon energies < 20 keV and cavities of mm dimensions are required for large cavity theory to be suitable at ^{192}Ir photon energies around 300 keV.



Conclusions: The question whether to report $D_{m,m}$ or $D_{w,m}$ arises when using MBDCAs for BT similar to in external beam therapy. However in BT the additional problem of deciding appropriate cavity dimensions arises due to the short ranges of secondary electrons. Free radicals from DNA bound water of nm dimensions contribute to complex DNA damage and cell killing and may be the most important water compartment in cells which would imply use of ratios of mass-collision stopping-powers for converting D_m into $D_{w,m}$ in BT as used in external beam therapy. Stopping power ratios vary little with energy and lead to numerical values for $D_{w,m}/D_{m,m}$ similar to those reported for other radiotherapy modalities. Mass energy absorption coefficient ratios imply large differences in D_m /$D_{w,m}$ over the BT energy range and to those obtained in external beam therapy.

OC-0085
Phase I/II clinical trial of a 3D real time array dosimeter to determine the dose to the rectum in pelvic radiotherapy
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THIS ABSTRACT HAS BEEN WITHDRAWN BY THE AUTHORS

PROFFERED PAPERS: GEC-ESTRO 2: GYNAE 1

OC-0086
Late morbidity following image guided adaptive brachytherapy (IGABT) in 533 patients with cervical cancer
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Purpose/Objective: To analyse late urogenital (UG), gastrointestinal (GI) and vaginal (VG) morbidity in patients treated for cervical cancer by IGABT in a multicentre setting.
Materials and Methods: RetroEMBRACE is a retrospective collection of data from patients treated for cervical cancer by IGABT using the GEC-ESTRO guidelines. At present, 796 patients have been registered from 12 institutions. Detailed data on morbidity grade 1-5 (CTCAE, V3.0) has been entered in 533 patients from 5 institutions. In these patients, FIGO-stage was IB1-IIA/IIB/IIIA-IVAB in 28%/48%/24%. Eighty-four percent were squamous cell carcinomas. In all patients IGABT was preceded by 3D conformal radiotherapy or Intensity Modulated Radiotherapy with mean dose of 46 ±3 Gy in 26 ±2 fractions and weekly concomitant cisplatinum in 76%. A nodal boost of 57 ±3 Gy was given to 16% and a parametrial boost of 55 ±2 Gy was given to 4%.